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(54) **MAINTAINING FLOW RATE OF A FLUID**

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(58) **Field of Classification Search** 137/206, 137/209, 12, 263; 141/21, 67, 91, 95
See application file for complete search history.

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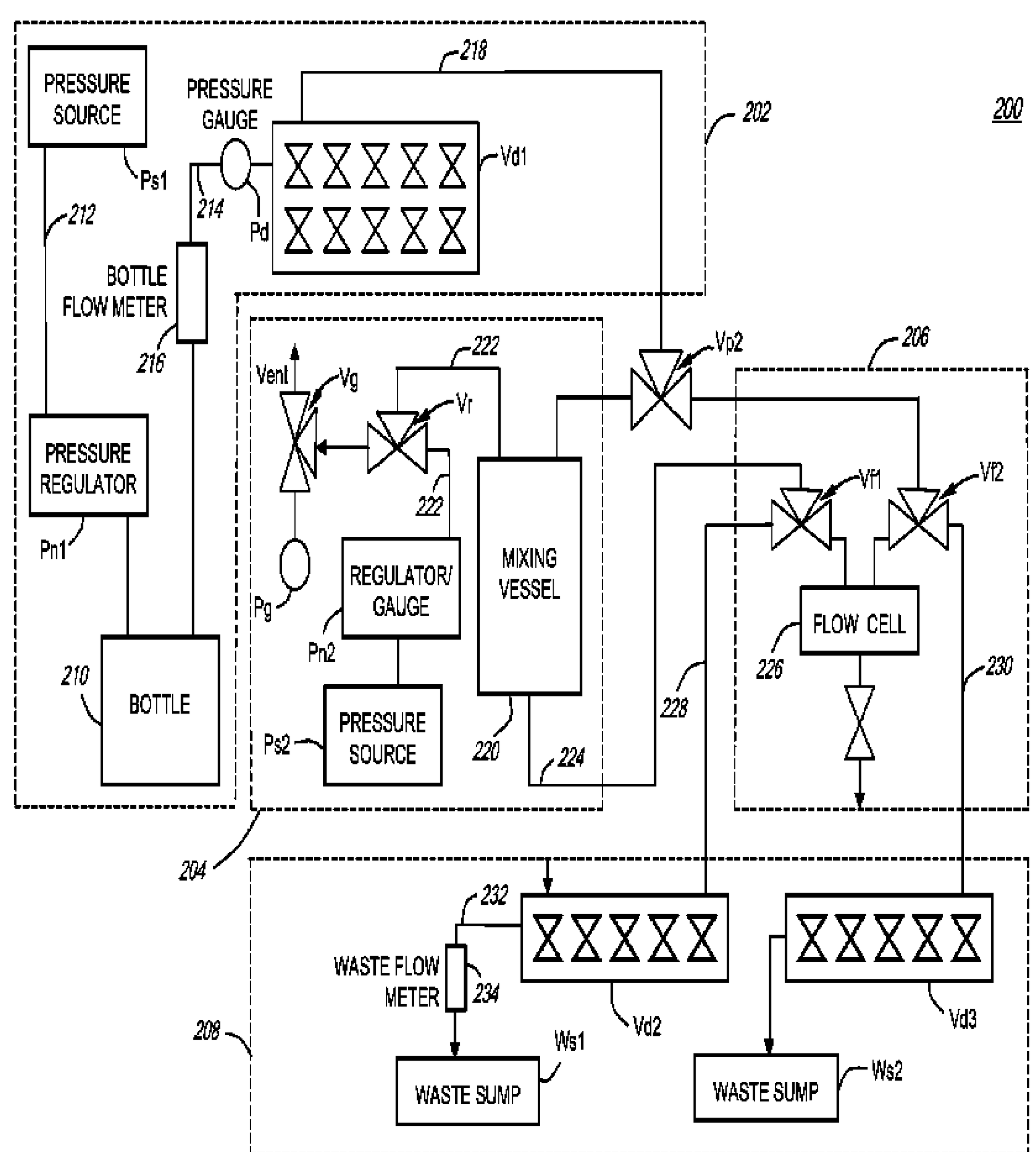
(57) **ABSTRACT**

A pressure gauge may be coupled to a supply line which carries liquid from a bottle to either one or more mixing vessels and/or one or more reactors in a combinatorial processing tool. A control device may monitor the pressure measured by the pressure gauge, and the control device may be configured to change the pressure supplied to the bottle based on a comparison of the measured pressure to a pre-determined pressure value. The control device may adjust the pressure provided to the bottle using a pressure regulator coupled to the pressure source. By changing the pressure provided to the bottle, the control device may maintain a relatively constant flow rate of fluids from the liquid source into one or more mixing vessels and/or the one or more reactors.

13 Claims, 5 Drawing Sheets



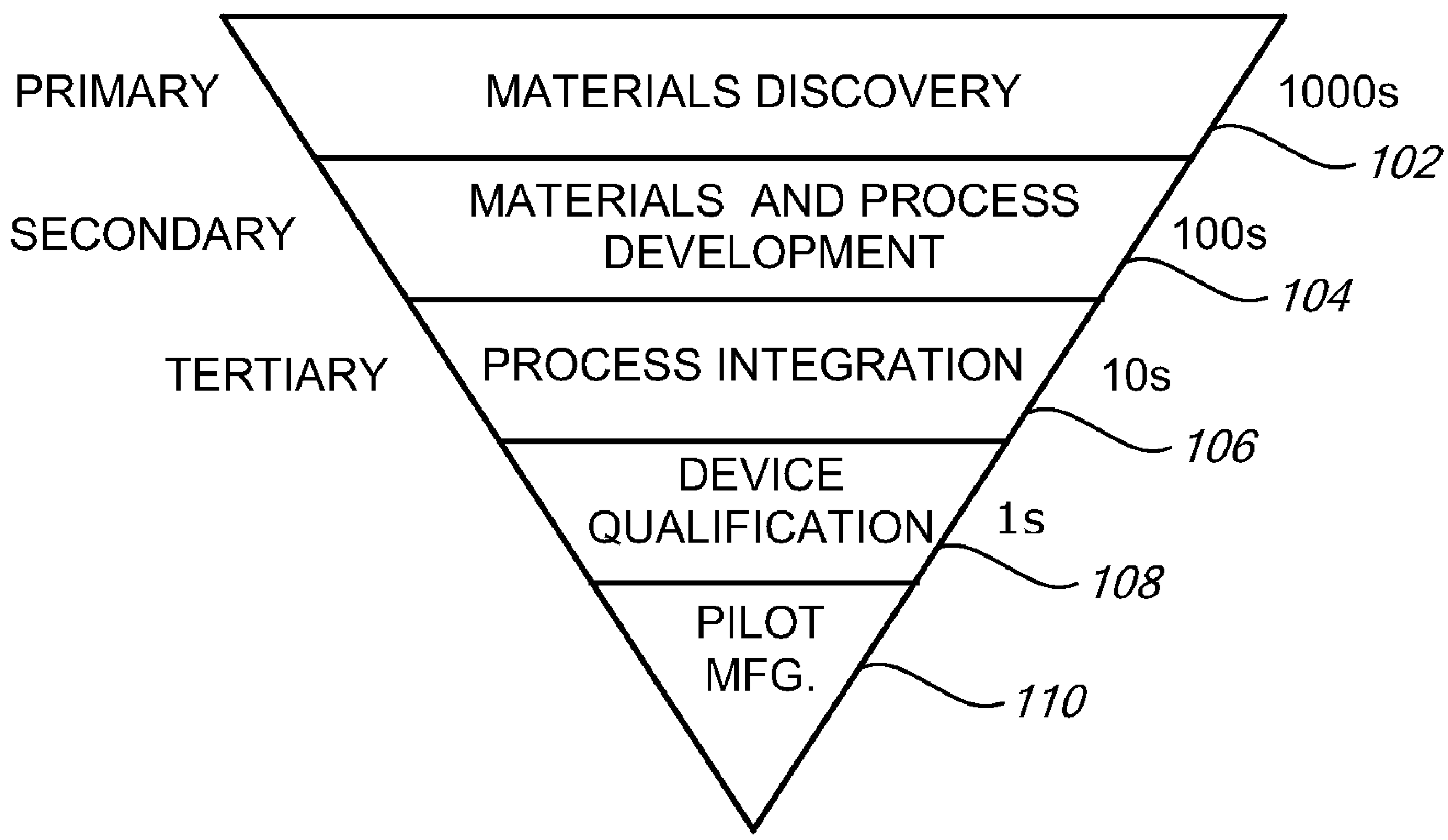

PRIMARY
MATERIALS DISCOVERY
1000s
102
SECONDARY
MATERIALS AND PROCESS DEVELOPMENT
100s
104
TERTIARY
PROCESS INTEGRATION
10s
106
DEVICE QUALIFICATION
1s
108
PILOT MFG.
110

FIG. 1A

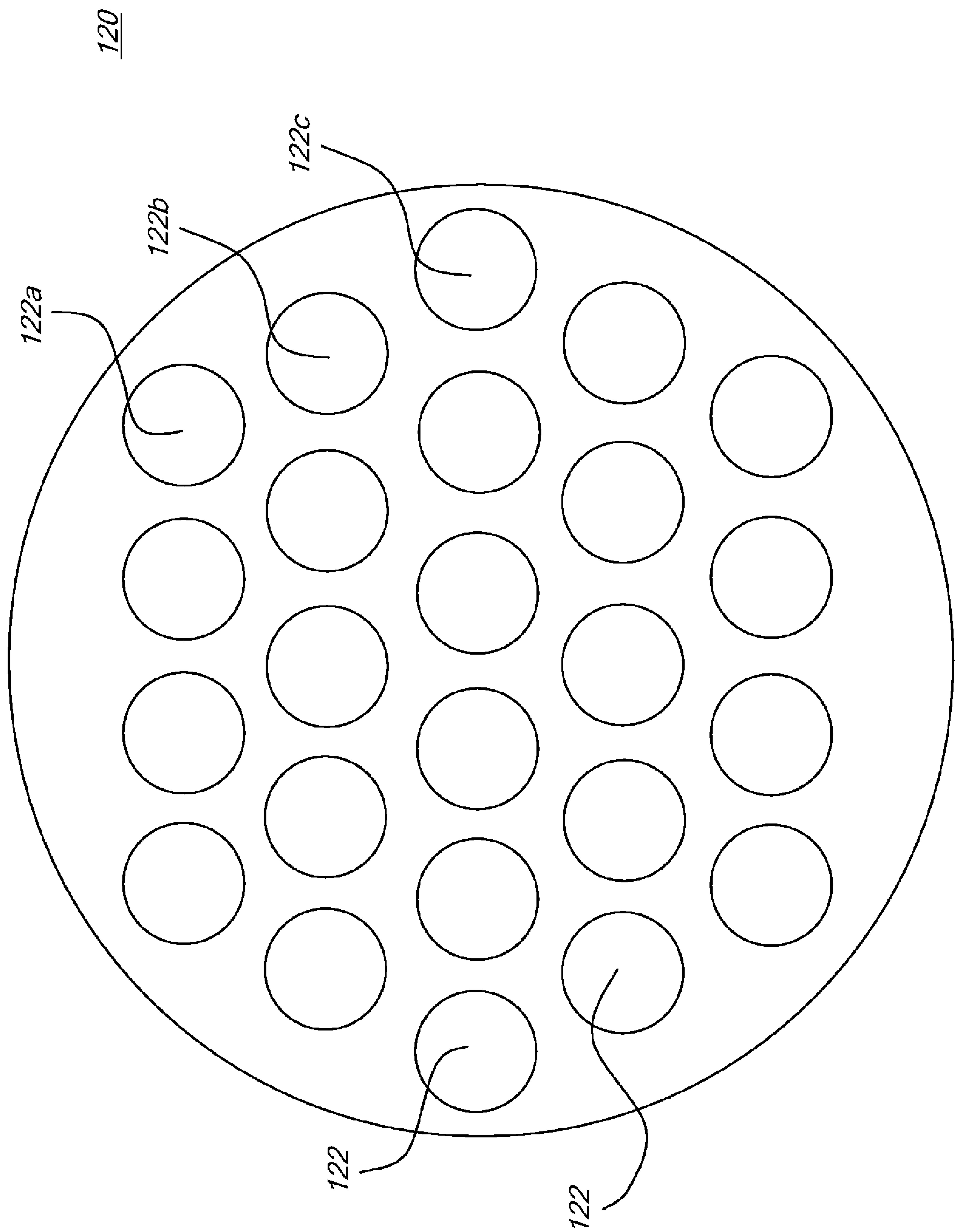
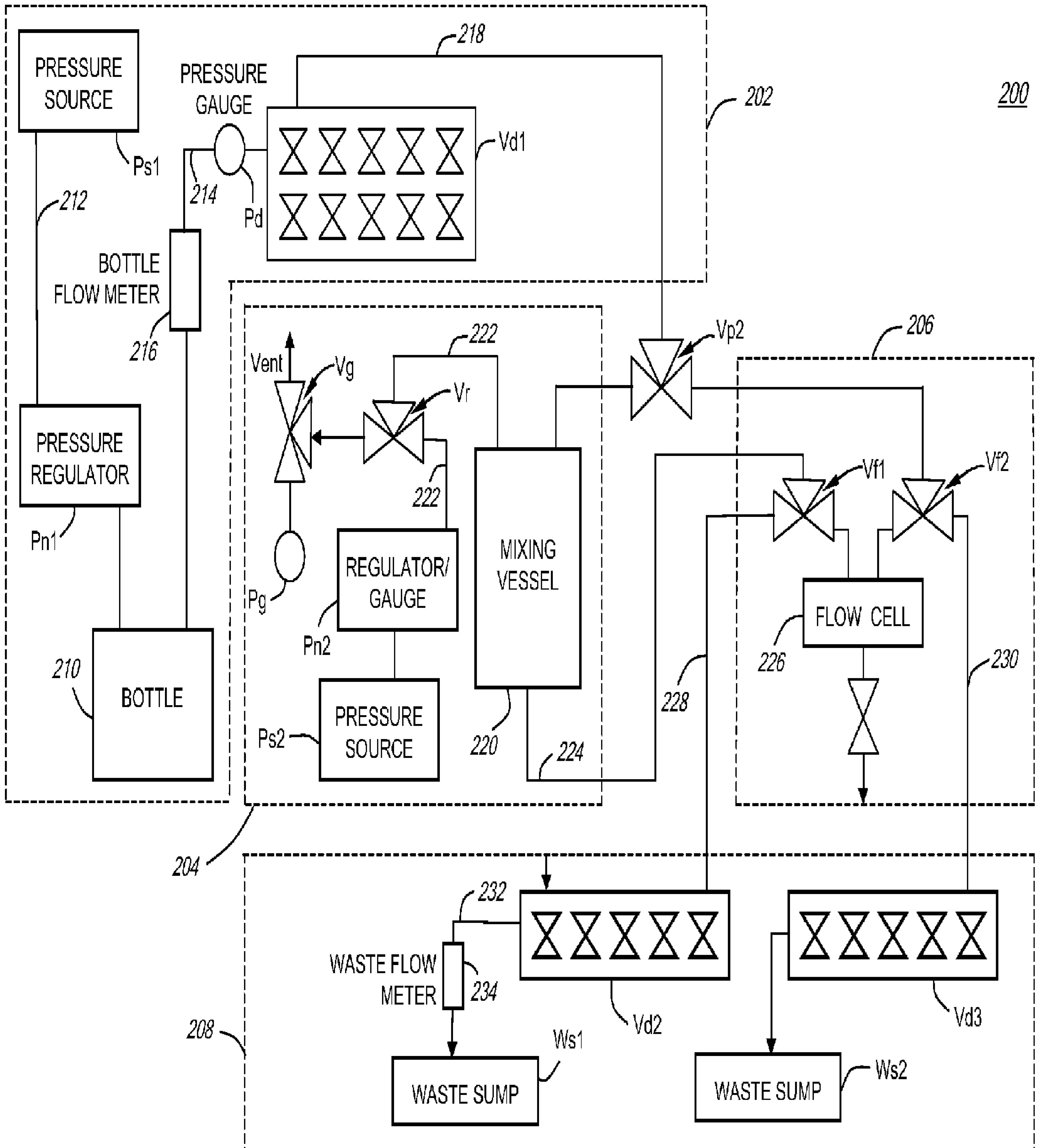


FIG. 1B



200
202
PRESSURE SOURCE
Ps1
212
PRESSURE GAUGE
214
Pd
218
Vd1
BOTTLE FLOW METER
216
PRESSURE REGULATOR
Pn1
210
BOTTLE
Vent
Vg
222
Vr
222
Pg
REGULATOR/ GAUGE
Pn2
PRESSURE SOURCE
Ps2
MIXING VESSEL
220
224
204
Vp2
206
Vf1
Vf2
FLOW CELL
226
228
230
208
232
WASTE FLOW METER
234
Vd2
Vd3
WASTE SUMP
Ws1
WASTE SUMP
Ws2

FIG. 2

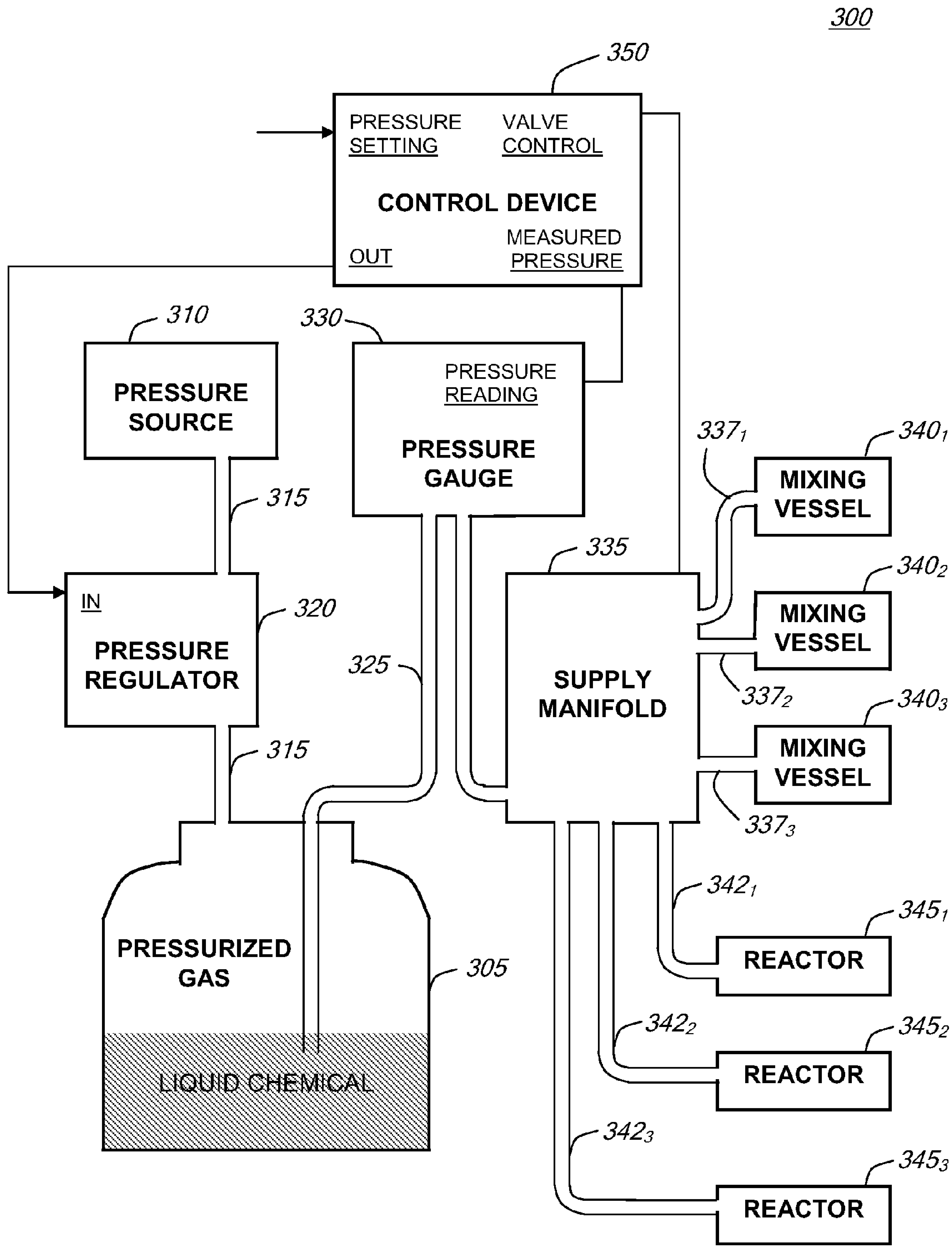

300
350
PRESSURE SETTING
VALVE CONTROL
CONTROL DEVICE
OUT
MEASURED PRESSURE
310
PRESSURE SOURCE
330
PRESSURE READING
PRESSURE GAUGE
315
IN
PRESSURE REGULATOR
320
325
315
335
SUPPLY MANIFOLD
337₁
340₁
MIXING VESSEL
340₂
MIXING VESSEL
337₂
340₃
MIXING VESSEL
337₃
342₁
345₁
REACTOR
342₂
345₂
REACTOR
342₃
345₃
REACTOR
PRESSURIZED GAS
305
LIQUID CHEMICAL

FIG. 3

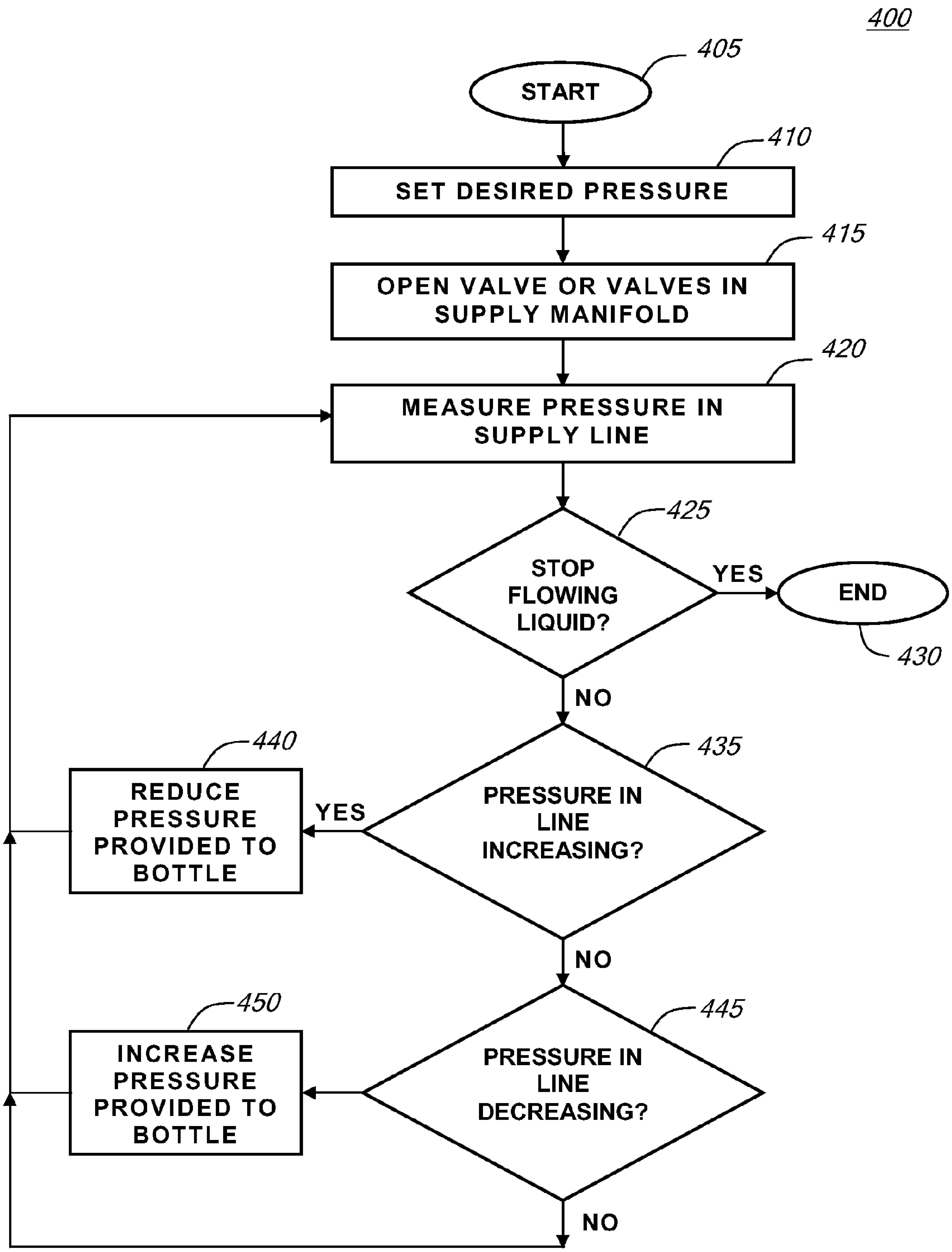

400
405
START
410
SET DESIRED PRESSURE
415
OPEN VALVE OR VALVES IN SUPPLY MANIFOLD
420
MEASURE PRESSURE IN SUPPLY LINE
425
STOP FLOWING LIQUID?
YES
END
430
NO
440
REDUCE PRESSURE PROVIDED TO BOTTLE
YES
435
PRESSURE IN LINE INCREASING?
NO
450
INCREASE PRESSURE PROVIDED TO BOTTLE
445
PRESSURE IN LINE DECREASING?
NO

FIG. 4

MAINTAINING FLOW RATE OF A FLUID

GOVERNMENT RIGHTS IN THIS INVENTION

This invention was made with U.S. government support under contract number H94003-07-C-0712. The U.S. government has certain rights in this invention.

BACKGROUND

1. Field of the Invention

Implementations of various technologies described herein generally relate to substrate processing.

2. Description of the Related Art

The following descriptions and examples do not constitute an admission as prior art by virtue of their inclusion within this section.

To achieve the desired performance enhancement for each successive generation of silicon integrated circuits (ICs), semiconductor manufacturing has become increasingly reliant on new materials and their integration into advanced process sequences. Unfortunately, typical semiconductor manufacturing equipment is not well suited for materials exploration and integration. Issues impacting the use of typical semiconductor manufacturing equipment include difficulty in changing process materials and chemicals rapidly, limited ability to integrate and sequence multiple materials or chemicals in a single reactor or process chamber, high equipment cost, large sample size (300 mm wafer) and inflexible process/reactor configurations. To complement traditional manufacturing tools, a need has arisen for process equipment that facilitates fast testing of new materials and materials processing sequences over a wide range of process conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

Implementations of various technologies will hereafter be described with reference to the accompanying drawings. It should be understood, however, that the accompanying drawings illustrate only the various implementations described herein and are not meant to limit the scope of various technologies described herein.

FIG. **1**A illustrates a schematic diagram for implementing combinatorial processing in connection with implementations of various technologies described herein.

FIG. **1**B illustrates an exemplary substrate containing multiple regions for combinatorial processing according to implementations of various technologies described herein.

FIG. **2** illustrates a schematic diagram of a combinatorial processing tool according to implementations of various technologies described herein.

FIG. **3** illustrates a system for maintaining a relatively constant flow rate of a fluid according to implementations of various technologies described herein.

FIG. **4** is a flow diagram illustrating a method for maintaining a relatively constant flow rate of a fluid according to implementations of various techniques described herein.

DETAILED DESCRIPTION

The following paragraphs generally describe one or more implementations of various technologies and techniques directed to maintaining a relatively constant flow rate of a fluid in a combinatorial processing tool. In one implementation, the fluid may be a liquid chemical used in the combinatorial processing tool. A pressurized gas source may be

coupled to a bottle containing the fluid, and the gas source may provide a pressure to the fluid in the bottle sufficient to push the fluid out of the bottle and through a supply line. The supply line may be coupled to a supply manifold which may be configured to supply the liquid to one or more vessels and/or one or more reactors within the combinatorial processing tool.

If the pressure supplied by the pressure source is constant, variations in the state of the combinatorial processing tool, such as variations in the number of vessels to which the liquid is supplied, may result in a variation of the fluid flow rate within the combinatorial processing tool. Accordingly, implementations of various techniques described herein may be used to maintain a relatively constant flow rate of the fluid regardless of the state of the combinatorial processing tool.

Parts of the tool (e.g., flow cells) may be occasionally calibrated to flow fluids at a specific rate. Monitoring a pressure within the tool and adjusting the pressure applied to fluids within a source chemical bottle based on the monitored pressure maintains the flow rate calibration of the tool. Maintaining the flow rate calibration of the tool also improves combinatorial processing across multiple regions, in that the flow in the multiple regions may be more predictable.

Additionally, the tool may have varying flow demands (e.g., if different numbers of flow cells are operating). For example, an increase in fluid flow demand on the source chemical bottle can reduce the level of the chemical bottle more quickly or the additional resistance in the multiple lines may require adjustments. Various techniques described herein may be used to increase the pressure in the bottle and therefore can be used to compensate for the increased fluid flow demand.

In one implementation, a relatively constant fluid flow rate may be achieved by monitoring the pressure within the supply line and varying the pressure supplied to the bottle in response to changes in the pressure within the supply line.

One or more implementations of various techniques for maintaining a relatively constant fluid flow rate will now be described in more detail with reference to FIGS. **1**-**4** in the following paragraphs.

The discussion below is directed to certain specific implementations. It is to be understood that the discussion below is only for the purpose of enabling a person with ordinary skill in the art to make and use any subject matter defined now or later by the patent "claims" found in any issued patent herein.

Combinatorial processing may include any processing, including semiconductor processing, which varies the processing conditions across one or more substrates. As used herein, a substrate may be, for example, a semiconductor wafer, a portion of a semiconductor wafer, solar photovoltaic circuitry, or other semiconductor substrate. The term "substrate" includes a coupon, which is a diced portion of a wafer, or any other device on which semiconductor processes are performed. The coupon or substrate may optionally contain one die, multiple dice (connected or not through the scribe), or portion of die with useable test structures. In some implementations, multiple coupons, or die can be diced from a single wafer and processed combinatorially.

Combinatorial processing is performed by varying processing conditions across multiple substrates, multiple regions of a single substrate, or a combination of the two. Processing conditions may include, for example, chemical formulation, fluid flow rates, temperatures, reaction times, concentrations, agitation or stirring, and the like. For example, a first region of a substrate may be processed using a first process condition (e.g., applying a chemical at a first temperature) and a second region of the substrate may be processed using a second process condition (e.g., applying the chemical at a second temperature). The results (e.g., the measured characteristics of the processed regions) are evaluated, and none, one, or both of the process conditions may be selected as suitable candidates for larger scale processing (e.g., further combinatorial processing or deposition on a full wafer). Techniques for combinatorial processing are described in U.S. patent application Ser. No. 11/352,077, entitled "Methods For Discretized Processing and Process Sequence Integration of Regions of a Substrate," which is incorporated herein by reference.

Several combinatorial processing tools can be used. One type of tool may include a reactor block that has several openings (e.g., cylindrical openings) that define individual reactors on a single substrate. Each of the openings may further include a sleeve that creates a seal with the substrate to contain processing fluids or chemicals within a single reactor. For example, a reactor block may include 28 openings that define 28 regions on a substrate. Each of the 28 regions can be processed using varying process conditions, or multiple regions can have the same processing conditions. For example, seven sets of processing conditions can be performed across four regions each. Each region can then be characterized using various techniques (e.g., electrical test, microscopy), and useful or beneficial techniques and/or conditions can be selected.

Other combinatorial processing may be performed in a manner that is not site isolated. For example, a wafer can be divided into many small coupons, each of which can be processed using different conditions. Using another example, a wafer can be processed using a gradient approach, where the processing varies over the substrate.

FIG. **1**A illustrates a schematic diagram **100** for implementing combinatorial processing in connection with implementations of one or more technologies described herein. The schematic diagram **100** illustrates that the relative number of combinatorial processes that run with a group of substrates decreases as certain materials and/or processes are selected. Generally, combinatorial processing includes performing a large number of processes during a first screen, selecting promising candidates from those processes, performing the selected processing during a second screen, selecting promising candidates from the second screen, and so on. In addition, feedback from later stages to earlier stages can be used to refine the success criteria and provide better screening results.

For example, thousands of materials are evaluated during a materials discovery stage **102**. Materials discovery stage **102** is also known as a primary screening stage performed using primary screening techniques. Primary screening techniques may include dividing wafers into coupons and depositing materials using varied processes. The materials are then evaluated, and promising candidates are advanced to the secondary screen, i.e., materials and process development stage **104**. Evaluation of the materials may be performed using metrology tools such as electronic testers and imaging tools, e.g., microscopes.

The materials and process development stage **104** may evaluate hundreds of materials (i.e., a magnitude smaller than the primary stage) and may focus on the processes used to deposit or develop those materials. Promising materials and processes are again selected, and advanced to the tertiary screen or process integration stage **106**, where tens of materials and/or processes and combinations are evaluated. The tertiary screen or process integration stage **106** may focus on integrating the selected processes and materials with other processes and materials.

The most promising materials and processes from the tertiary screen are advanced to device qualification stage **108**. In device qualification, the materials and processes selected are evaluated for high volume manufacturing, which normally is conducted on full wafers within production tools, but need not be conducted in such a manner. The results are evaluated to determine the efficacy of the selected materials and processes. If successful, the use of the screened materials and processes can proceed to the manufacturing stage **110**.

The schematic diagram **100** is an example of various techniques that may be used to evaluate and select materials and processes for the development of semiconductor devices. The descriptions of primary, secondary, etc. screening and the various stages **102-110** are arbitrary and the stages may overlap, occur out of sequence, be described and be performed in many other ways.

FIG. **1**B illustrates a substrate **120** having multiple regions for combinatorial processing in accordance with various techniques described herein. Substrate **120** includes several regions **122** on which semiconductor processes can be performed. For example, the regions **122***a*, **122***b*, and **122***c* may each have an electroless layer deposited on them. The region **122***a* may use a first chemical formulation, the region **122***b* may use a second chemical formulation, and the region **122***c* may use a third chemical formulation. The resulting layers can be compared to determine the relative efficacy of each of the formulations. None, one, or more of the formulations can then be selected to use with further combinatorial processing or larger scale processing (e.g., manufacturing). Any process variable (e.g., time, composition, temperature) or process sequencing can be varied using combinatorial processing.

As discussed above, each of the regions **122** may or may not be site isolated. Site isolation refers to a condition where the regions **122** can be processed individually and independently without interference from neighboring regions. For example, one or more of the regions **122** may include a sleeve having an end that forms a fluid seal with the substrate **120**. The sleeve is configured to contain processing fluids (e.g., chemicals), and is made from a material (e.g. polytetrafluoroethylene (PTFE)) that does not react with the processing chemicals used. The chemicals do not leak out of the region into which they were dispensed, and each region **122** can be processed and evaluated individually.

Each of the regions **122** may be processed using a cell of a combinatorial processing tool, as described in FIG. **2**. The tool is calibrated so that processing in each of the regions **122** is consistent and comparable. Using techniques described herein, pressure within the combinatorial processing tool may be monitored and the pressure supplied to the chemical supply bottle can be adjusted so that the flow rate in the flow cells stays consistent and calibrated. With these techniques, processed regions across one or multiple substrates may show reliable results that can be compared and characterized when performing combinatorial processing.

Combinatorial Processing Tool

FIG. **2** illustrates a schematic diagram of a combinatorial processing tool **200** according to implementations of one or more technologies described herein. The combinatorial processing tool **200** illustrated in FIG. **2** may be a wet processing tool and may be a portion of a larger combinatorial processing tool. Portions of the combinatorial processing tool **200** may be replicated several times within a larger combinatorial processing tool such that a larger number of variations in substrate processing conditions may be achieved.

The combinatorial processing tool **200** illustrated in FIG. **2** may be divided into four parts. A chemical supply portion **202** may supply chemicals to a chemical mixing portion **204** and a site isolated reactor portion **206**. The chemical mixing portion **204** may be used for mixing various chemicals, e.g., liquid chemicals, into solutions which may be applied to various locations on a substrate in the reactor portion **206**. The reactor portion **206** may contain a site isolated reactor and may apply the solutions to the substrate or portions of the substrate and may subject the substrate or portions thereof to various processing conditions. The reactor portion **206** may be coupled to a waste portion **208** of the combinatorial processing tool **200**. The waste portion **208** may be used to capture waste chemicals which were not used during substrate processing.

The supply portion **202** of the combinatorial processing tool **200** may include a bottle **210** containing a liquid chemical. The chemical may be applied to the substrate or may be mixed with another chemical to form a solution which is to be applied to the substrate. As illustrated in FIG. **2**, a pressure source PS**1** and a pressure regulator Pn**1** may be coupled to the bottle **210** via a pressure supply line **212**. Together the pressure source PS**1** and the pressure regulator Pn**1** may provide a pressurized gas, such as Nitrogen, at a regulated pressure to the bottle **210** via the supply line **212**. In this manner, the pressurized gas may be used to push the liquid chemical out of the bottle **210** and into a line **214** connecting the bottle **210** to a supply manifold Vd**1**. A flow meter **216** and a pressure transducer Pd may be coupled to the line **214**. The flow meter **216** may monitor the flow rate of liquids through the line **214** and the pressure gauge Pd may monitor the pressure within the line **214**.

The supply manifold Vd**1** may contain a plurality of two-way and/or multi way valves connecting the bottle **210** to a plurality of mixing cells/vessels within the combinatorial processing tool **200**. Furthermore, in lieu of a single bottle **210**, a plurality of bottles containing various chemicals may be coupled to the supply manifold Vd**1** such that the supply manifold Vd**1** may supply various chemicals to multiple mixing portions or multiple site isolated reactor portions of the combinatorial processing tool **200**. Additionally, in lieu of a single supply manifold Vd**1**, a plurality of supply manifolds Vd**1** may be present in the combinatorial processing tool **200**. Together the plurality of bottles, valves, and supply manifolds may enable the supply of various chemicals and chemical mixtures to the mixing portion **204** and the site isolated reactor portion **206** of the combinatorial processing tool **200**.

The line **214** coupling the bottle **210** to the supply manifold Vd**1** may be coupled to a valve, e.g., a multi-way valve, within the supply manifold Vd**1** such that the supply manifold Vd**1** may control the flow of chemicals from the bottle **210** to the mixing portion **204** or the reactor portion **206** of the combinatorial processing tool **200**.

The output of the valve in the supply manifold Vd**1** may be coupled via a line **218** to a valve Vp**2**. The valve Vp**2** may be a multi-way valve which controls the flow of fluids/chemicals from the supply manifold Vd**1** into either the mixing portion **204**, site-isolated reactor portion **206**, or both.

The mixing portion **204** of the combinatorial processing tool **200** is provided to allow thorough solution mixing of chemicals provided by supply portions. In order to form a solution, a plurality of chemicals may flow from the supply portion **202**, e.g., the bottle **210**, into different mixing vessels in the mixing portion **204**. The mixing vessel **220** may then mix the chemicals to form solutions. The mixing portion **204** may also provide accurate temperature and pH control of a solution being mixed in the mixing portion **204**.

A pressure source Ps**2** and a pressure regulator Pn**2** may be coupled to the mixing vessel **220** via a valve Vr and a supply line **222**. Together the pressure source PS**2** and the pressure regulator Pn**2** may provide a pressurized gas, e.g., Nitrogen, at a regulated pressure to the mixing vessel **220** via the valve Vr and the supply line **222**. An outlet of the valve Vr may be coupled to another valve Vg to vent pressure within the supply line **222**. The pressure in the supply line **222** may be measured by a pressure transducer Pg.

The pressurized gas provided by the pressure source Ps**2** and the pressure regulator Pn**2** may push the mixed chemicals in the mixing vessel **220** through a line **224** and into the site-isolated reactor portion **206** of the combinatorial processing tool **200**. The mixed chemicals may flow through a valve Vf**1** and into a flow cell **226**. The flow cell **226** may be one portion of a site isolated reactor, and may be used to apply the mixed chemicals to a portion or portions of a substrate under processing in the site-isolated reactor portion **206** of the combinatorial processing tool **200**. The flow cell **226** may be one of a series of parallel cells forming site-isolated reactors which may be configured to effect site-isolated processing on proximate regions on the substrate. Each of the flow cells may be configured to effect site isolated processing, for example, by flowing fluids (e.g., mixed chemicals) onto proximate regions on the substrate. Chemicals may be provided to the flow cell **226** and, consequently, to a substrate via the supply manifold Vd**1**.

A rate of fluid flow into the flow cell **226** may be calibrated before the tool **200** is used so that the combinatorial processing of the tool **200** is reliable and so that the multiple regions (e.g., regions **122**) of a substrate can be compared. The techniques described herein monitor pressure within a supply line of the combinatorial processing tool **200** and adjust pressure in the bottle **210** to maintain a constant fluid flow rate into the flow cell **226**. The flow rate out of the bottle changes with changes in pressure. Thus, maintaining a consistent pressure within a supply line of the combinatorial processing tool **200** can be used to maintain fluid flow rate calibration of the tool **200**.

In some implementations, different numbers of flow cells **226** may be operating simultaneously. For example, during one operation only one flow cell may be open, while during another, eight may be open. The variability of the number of flow cells in operation changes the flow volume demands. Using the techniques described herein, the pressure in the bottle **210** can be adjusted during changes in the number of flow cells operating within the combinatorial processing tool **200** to maintain fluid flow rate calibration and consistent processing across multiple regions.

After exposing the substrate to the desired amount of chemicals, unused chemicals may exit the flow cell **226** through valve Vf**1** and waste line **228** or through valve Vf**2** and waste line **230**. Waste line **228** may be coupled to a waste manifold Vd**2**, and waste line **230** may be coupled to waste manifold Vd**3**. The waste manifolds may be coupled to waste sumps (e.g., waste sump Ws**1** and waste sump Ws**2**) and the waste manifolds may be used to divert chemicals into specific waste sumps. A waste line **232** may couple a waste manifold Vd**2** to a waste sump Ws**1**. Furthermore, a waste flow meter **234** may be coupled to the waste line **232** to measure a flow rate of waste liquids flowing into the waste sump Ws**1**.

The flow meters (e.g., flow meter **216** and flow meter **234**) may be any type of flow meter available. For example, the flow meters may be ultrasonic flow meters which measure the travel time of ultrasonic waves through a liquid and calculates a flow rate of the liquid based on the measured travel time of the ultrasonic waves. The flow meters may also be magnetic flow meters which measure changes in a magnetic field applied to a liquid to determine a rate of liquid flow.

Maintaining a Relatively Constant Fluid Flow Rate of a Fluid

As described above, the supply portion **202** of the combinatorial processing tool **200** may supply fluids (e.g., liquid chemicals) to the mixing portion **204** and the reactor portion **206** of the combinatorial processing tool **200**. For example, the bottle **210** may supply a fluid via the supply line **214** and the supply manifold Vd**1** to the mixing portion **204** and the reactor portion **206** of the combinatorial processing tool **200**.

In combinatorial processing tools, in order to reliably and consistently process multiple regions of a substrate, it may be desirable to maintain a relatively constant fluid flow rate into the mixing portion **204** and/or the reactor portion **206** of the combinatorial processing tool. However, in some circumstances the flow rate of the fluid may be affected by the state of the combinatorial processing tool. For example, if the pressure applied to the bottle **210** by the pressure source Ps**1** is constant and a valve in the supply manifold Vd**1** is opened to couple the supply line to a single flow cell **226**, the flow rate out of the bottle **210** may be a first value. However, if more valves in the supply manifold Vd**1** are opened to supply fluids from the bottle **210** to multiple flow cells, the flow rate within the flow cells may be a different value than the first value. Additionally, if the pressure applied to the bottle **210** by the pressure source Ps**1** is constant, the flow rate within the flow cells may also change or vary based on the height of the liquid in the bottle **210**.

Consequently, a need exists for maintaining a relatively constant flow rate within the flow cells regardless of the state of the combinatorial processing system (e.g., number of vessels into which the fluid is flowing, height of liquid in the bottle, etc.).

Implementations described herein provide technologies and devices for maintaining a relatively constant fluid flow rate into destination vessels (e.g., mixing vessels and/or flow cells). According to one implementation, a relatively constant fluid flow rate may be maintained by monitoring a pressure in a supply line coupled to the bottle containing the liquid and varying the pressure provided to the bottle based on the monitored pressure.

FIG. **3** illustrates a system **300** which maintains a relatively constant flow rate of fluids according to implementations of various technologies described herein. The system **300** includes a bottle **305** which contains a fluid (e.g., a liquid chemical). A pressurized gas may be supplied to the bottle **305** via a pressure source **310**. The pressure source **310** may supply the pressurized gas to the bottle **305** through a gas supply line **315**. A pressure regulator **320** may be coupled to the gas supply line **315** and may be configured to regulate an amount of pressurized gas provided to the bottle **305** from the pressure source **310**.

As illustrated in FIG. **3**, a liquid supply line **325** may be coupled to or inserted into the bottle **325** such that a first end of the supply line **325** is immersed into the liquid chemical within the bottle **305**. A second end of supply line **325** may be coupled to a supply manifold **335**.

The supply manifold **335** may contain a plurality of valves. The inputs of the valves within the supply manifold **335** may be coupled, via supply lines, to a plurality of bottles containing chemicals (e.g., bottle **305**). The outputs of the valves within the supply manifold **335** may be coupled to a plurality of mixing vessels **3401-3** via secondary supply lines **3371-3**. Furthermore, the outputs of the valves within the supply manifold **335** may be coupled to a plurality of reactors **3451-3** via secondary supply lines **3421-3**. Consequently, the mixing vessels **3401-3** and reactors **3451-3** may be configured to receive the fluids from the plurality of bottles via the secondary supply lines **3371-3** and **3421-3**. Additionally, in some implementations, outputs (not shown) of the mixing vessels **340** may provide mixed chemicals to the reactors **345**, as is further described regarding FIG. **2**.

If varying numbers of mixing vessels **340** and reactors **345** are being supplied with chemicals, the flow volume demands from the bottle **305** may change. In order to maintain calibrated fluid flow rate through the secondary supply lines **3371-3** and **3421-3** and into the mixing vessels **340** and reactors **345** so that multiple regions of a substrate can be reliably and consistently processed, the pressure of the bottle **305** may be varied using the pressure regulator **320**. For example, during one operation fluid may flow into all three mixing vessels **340** and into all three reactors **345**. In a subsequent operation, fluid may flow into only one of the reactors **345**. During this change, the pressure in the line **325** may change, necessitating a change in the pressure supplied to the bottle **305** to maintain fluid flow rate through the secondary supply lines **3371-3** and **3421-3** and into the mixing vessels **340** and reactors **345**.

According to one implementation, a pressure gauge **330** may be coupled to the supply line **325** such that the pressure gauge **330** measures a pressure within the supply line **325**. The pressure gauge **330** may be any type of pressure gauge or pressure transducer. For example, the pressure gauge **330** may be a fluoro-polymer based pressure transducer.

The pressure gauge **330** may be coupled to the supply line **325** closer to the supply manifold **335** than to the bottle **305**. According to one implementation, the pressure gauge **330** may be located as close to the supply manifold **335** as possible. The pressure gauge **330** may be located as close to the supply manifold **335** as possible such that there is a minimum pressure drop between the pressure gauge **330** and the supply manifold **335**. The lower the pressure drop between the pressure gauge **335** and the supply manifold **335**, the more accurately the system **300** illustrated in FIG. **3** may maintain a relatively constant fluid flow rate into the mixing vessels **340** and reactors **345** regardless of the state of the combinatorial processing system.

The pressure gauge **330** may supply a pressure reading indicative of the pressure within the supply line **325** to an input of a control device **350**. The control device **350** may be, for example, a computer system containing one or more processors, memory (e.g., hard disk drive(s), random access memory, etc.), devices for receiving input from a user (e.g., keyboard, mouse, etc.), communication devices (e.g., network controllers, serial ports, etc.), and/or devices for outputting data (e.g., printers, monitors, data storage, etc.).

The control device **350** may be configured to receive as input a recipe for processing a substrate or substrates within the combinatorial processing tool **200**. A recipe may be a set of parameters that may be specified by a user, for example, for performing the combinatorial processing. A recipe may include such parameters as chemical types, flow rates, concentrations, sequences, reaction times, bottle pressures, etc.

The control device **350** may have a second input configured to receive a pre-determined pressure setting. The pre-determined pressure setting may correspond to a desired flow rate of the fluid through the combinatorial processing tool. The pressure setting may be specified using a recipe. Alternatively, the pressure setting can be determined by a set of instructions used to calculate the pressure setting based on other parameters (e.g., desired flow rates) or measured characteristics.

An output of the control device **350** may be coupled to the supply manifold **335** and may be configured to control the opening and closing of valves within the supply manifold **335**. Additionally, the control device **350** may also have an output (Out) coupled to the pressure regulator **320**.

As will be described further below with respect to FIG. **4**, the control device **350** may be configured to compare the pressure reading from the pressure gauge **330** to the pressure setting. Based on the results of the comparison, the control device **350** may be configured to modify the amount of pressure supplied to the bottle **305** by adjusting the pressure regulator **320**.

The system **300** illustrated in FIG. **3** may be a portion of, or used in combination with, the combinatorial processing tool **200** illustrated in FIG. **2** in order to maintain a relatively constant flow rate of fluid into mixing vessels and flow cells within the combinatorial processing tool **200**. For example, the pressure source **310**, pressure regulator **320**, bottle **305**, supply manifold **335**, mixing vessels **3401-3**, and reactors **3451-3** illustrated in FIG. **3** may be the same as the pressure source PS**1**, pressure regulator Pn**1**, bottle **210**, supply manifold Vd**1**, mixing vessel **220**, and flow cell **225** illustrated in FIG. **2**, respectively.

FIG. **4** illustrates a method **400** for maintaining a relatively constant fluid flow rate using the system **300** illustrated in FIG. **3** in accordance with implementations of various techniques described herein. Method **400** may be executed by the control device **350** illustrated in FIG. **3**.

In one implementation, method **400** may begin at step **405** when use of the combinatorial processing tool is commenced. At step **410**, a user of the combinatorial processing tool may indicate a desired pressure setting in the control device **350**. The control device **350** may use this desired pressure set point to adjust the pressure regulator **320**. The pressure setting may be a single pressure value, and the control device may attempt to keep a pressure in the supply line **325** close to the desired pressure setting in order to maintain a relatively constant fluid flow rate. Alternatively, the pressure setting may be a range including a high pressure threshold value and a low pressure threshold value. If the pressure setting is a range of values, the control device **350** may attempt to keep the pressure in the supply line **325** less than the high pressure threshold value and greater than the low pressure threshold value in order to maintain a relatively constant flow rate of fluids.

After a user has set the desired pressure setting, the control device **350** may adjust the pressure regulator **320** according to the pressure setting. This may cause pressure to be provided to the bottle **305** via the pressure source **310** and the supply line **315**.

At step **415**, the control device **350** may open a valve or valves in the supply manifold **335** which is/are coupled to the fluid supply line **325**. Opening the valves in the supply manifold **335** may cause the pressure supplied to the bottle **305** to push the fluid in the bottle **305** into the supply line **325** and out of the bottle **305**. The fluid may flow through the supply line **325**, through the supply manifold **335**, through the secondary supply lines **3371-3** and **3421-3** and into one or more mixing vessels **3401-3** and/or one or more reactors **3451-3**. The liquid chemical which flows into the reactor portion **206** of the combinatorial processing tool **200** may flow across one or more regions of a substrate undergoing combinatorial processing.

As the fluid flows through the supply line **325** and the supply manifold **335**, at step **420** the pressure gauge **330** may measure the pressure within the supply line **325** and provide a pressure measurement to the control device **350**. Next, at step **425** the control device **350** may determine if the flow of the liquid should be stopped. The flow of liquid may need to be stopped, for example, if the desired amount of chemical has flowed into the mixing vessel(s) and/or reactor(s). If the control device **350** determines that the flow of the liquid should be stopped, the control device **350** may turn off the valve or valves coupled to the supply line **325** thereby stopping the flow of the fluid and ending method **400** at step **430**.

However, if the control device **350** determines that the flow of fluids should continue, the control device **350** may proceed to step **435** to determine if the measured pressure in the supply line **325** is increasing. As described above, the pressure in the supply line **325** may change (e.g., increase) depending on the state of the combinatorial processing tool. For example, the pressure in the supply line **325** may increase or decrease if the number of mixing vessels or reactors to which the fluid is being flowed into decreased or increased, respectively.

The control device **350** may determine if the pressure in the supply line **325** is increasing by comparing the pressure measurement from the pressure gauge **330** to the pressure setting. If the measured pressure in the supply line **325** is greater than the pressure setting or greater than a high threshold of a pressure setting range, then it the pressure in the supply line **325** may be determined as increasing. Increases and decreases in pressure can also be compared to prior measurements in a trend line fashion with no adjustments being made as long as the flow is within the threshold range.

If the pressure in the supply line **325** is increasing, the control device **350** may reduce or decrease the amount of pressure supplied to the bottle **305** from the pressure source **310** (step **440**). The control device **350** may increase the amount of pressure supplied to the bottle **305** by adjusting the pressure regulator **320**. By reducing the pressure supplied to the bottle **305**, the pressure in the supply line **325** may be reduced and, as a consequence, a relatively constant flow rate of the fluid through the secondary supply lines **3371-3** and **3421-3** and into the mixing vessel(s) and/or reactor(s) may be maintained. After reducing the pressure supplied to the bottle **305**, the control device may return to step **420** to again measure the pressure in the supply line **325**.

However, if at step **435** the control device **350** determines that the pressure in the supply line **325** is not increasing, the control device **350** may proceed to step **445** to determine if the pressure within the supply line **325** is decreasing. The control device **350** may determine if the pressure in the supply line **325** is decreasing by comparing the pressure measurement from the pressure gauge **330** to the pressure setting. If the measured pressure in the supply line **325** is less than the pressure setting or less than a low threshold of a pressure setting range, the pressure in the supply line **325** may be decreasing.

If the pressure in the supply line **325** is decreasing, the control device **350** may proceed to step **450** to increase the amount of pressure supplied to the bottle **305** from the pressure source **310**. The control device may increase the amount of pressure supplied to the bottle **305** by adjusting the pressure regulator **320**. By increasing the pressure supplied to the bottle **305**, the pressure in the supply line **325** may be increased and, as a consequence, the flow rate of the fluid through the secondary supply lines **3371-3** and **3421-3** and into the mixing vessels **340** and reactors **345** may be maintained. After increasing the pressure supplied to the bottle **305**, the control device may return to step **420** to again measure of the pressure in the supply line **435**.

If at step **445** the control device **350** determines that the pressure in the supply line **325** is not decreasing, the pressure within the supply line **325** has not changed and consequently the fluid flow rate is relatively constant. Consequently, the control device **350** does not need to modify the amount of pressure supplied to the bottle **305** and, thus, the control device **350** may return to step **420** to again measure the pressure in the supply line **325**.

By increasing or decreasing pressure supplied to the bottle **305** based on the pressure in the supply line **325**, implementations described herein provide systems and technologies for maintaining a relatively constant flow rate of fluids in a combinatorial processing tool.

In one implementation, the pressure setting or the pressure setting range in the control device **350** may be periodically varied or modified. Modifications in the pressure setting or the pressure setting range may result in a new fluid flow rate in the combinatorial processing system. The system **300** illustrated in FIG. **3** and the method **400** illustrated in FIG. **4** may then maintain the new fluid flow rate within the system. The pressure setting or pressure setting range may be modified according to a recipe or calculated value, for example.

While the foregoing is directed to implementations of various technologies described herein, other and further implementations may be devised without departing from the basic scope thereof, which may be determined by the claims that follow. Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

What is claimed is:

1. A method for maintaining a predetermined fluid flow-rate, comprising:
- providing a pressure to a first vessel from a pressure source, wherein the first vessel contains a fluid for use in a semiconductor manufacturing process;
- flowing the fluid from the first vessel through a first supply line, into a manifold coupling a plurality of secondary supply lines to the first supply line, and into at least one second vessel coupled to at least one of the secondary supply lines;
- flowing the fluid from the at least one second vessel into a combinatorial processing tool having a plurality of site isolated reactors, wherein the fluid is a liquid;
- monitoring a pressure within the first supply line; and
- maintaining a predetermined fluid flow-rate through the secondary supply lines by adjusting a pressure provided to the first vessel based on the monitored pressure.

2. The method of claim **1**, further comprising:
- defining multiple regions of a substrate through the plurality of site isolated reactors of the combinatorial processing tool;
- processing the multiple regions of the substrate in a combinatorial manner by varying process conditions across the substrate; and
- wherein processing the multiple regions comprises flowing the fluid across at least one of the multiple regions of the substrate.

3. The method of claim **2**, wherein processing the multiple regions comprises varying the fluid flow rate across the multiple regions.

4. The method of claim **1**, further comprising:
- comparing increases and decreases of the pressure within the first supply line with previously recorded pressure values in a trend line fashion; and
- making no adjustments to the pressure provided to the first supply line so long as the fluid flow-rate through the secondary supply lines remains substantially the same.

5. The method of claim **1**, wherein maintaining the fluid flow-rate through the secondary supply lines by adjusting a pressure provided to the first vessel based on the monitored pressure comprises:
- determining if the monitored pressure is decreasing; and
- if so, increasing the pressure provided to the first vessel from the pressure source.

6. The method of claim **5**, wherein increasing the pressure provided to the first vessel from the pressure source comprises adjusting a pressure regulator such that the pressure provided to the first vessel from the pressure source is increased.

7. The method of claim **1**, wherein maintaining the fluid flow-rate through the secondary supply lines by adjusting a pressure provided to the first vessel based on the monitored pressure comprises:
- determining if the monitored pressure is increasing; and
- if so, decreasing the pressure provided to the first vessel from the pressure source.

8. The method of claim **7**, wherein decreasing the pressure provided to the first vessel from the pressure source comprises adjusting a pressure regulator such that the pressure provided to the first vessel from the pressure source is decreased.

9. The method of claim **1**, wherein maintaining the fluid flow-rate through the secondary supply lines by adjusting a pressure provided to the first vessel based on the monitored pressure comprises:
- determining if the monitored pressure is acceptable; and
- if so, maintaining the pressure provided to the first vessel from the pressure source.

10. The method of claim **5**, wherein determining if the pressure within the first supply line is decreasing comprises:
- comparing the monitored pressure to a low threshold; and
- if the monitored pressure is less than the low threshold, then determining that the monitored pressure is decreasing.

11. The method of claim **7**, wherein determining if the pressure within the first supply line is increasing comprises:
- comparing the monitored pressure to a high threshold; and
- if the pressure is greater than the high threshold, then determining that the monitored pressure is increasing.

12. The method of claim **9**, wherein determining if the monitored pressure is acceptable comprises:
- comparing the monitored pressure to a low threshold and a high threshold; and
- if the monitored pressure is greater than or equal to the low threshold and less than or equal to the high threshold then determining that the pressure is acceptable.

13. The method of claim **1**, wherein monitoring the pressure within the first supply line comprises, reading a pressure measurement from a pressure transducer coupled to the first supply line.

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